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Procedia Engineering 121 (2015) 1582 – 1589

**Procedia
Engineering**www.elsevier.com/locate/procedia

9th International Symposium on Heating, Ventilation and Air Conditioning (ISHVAC) and the 3rd
International Conference on Building Energy and Environment (COBEE)

The Optimization of the Personalized Fresh Air Ventilation and Individualized Radiation in the Hospital Ward

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Abstract

To a hospital ward, the temperature and humidity independent control system (THICACS) is very suitable to be applied. However, because of its expensive initial investment, the application of this kind of air-conditioning system is still limited. Based on the conventional THICACS, this paper adopt personalized ventilation and radiation in a triple ward to improve the performance of HVAC system. By simulating the distributions of several key parameters such as temperature and PMV, comparisons and validations are made between conventional and personalized THICACS. The result shows that the amount of the radiant panels are reduced almost 33.8% in personalized ventilation and radiation system. We can draw a conclusion that, by implementing the personalized ventilation to fresh air and the individualized radiation to terminal devices, we can reduce the laying area of the radiant panel and improve indoor comfort levels, which shows a great significance in advancing economics and energy-saving performance of THICACS.

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Peer-review under responsibility of the organizing committee of ISHVAC-COBEE 2015

Keywords: Personalized ventilation, Individualized radiation, THICACS, Energy-saving, Thermal comfort

1. Introduction

There was a total of approximately 7.8 billion m^2 of non-residential buildings in China in 2008, and about 4–5 million m^2 of new buildings are being built every year [1]. The energy consumption of air-conditioning systems represents a large proportion of the total energy consumption of non-residential buildings, usually 20–60% [2]. Thus, declining the energy consumption of air-conditioning systems is one of the important approaches to save energy in

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non-residential buildings [3].

The fundamental concepts of the THIC system is to modulate indoor air temperature and humidity separately. A cooling source of high temperature is utilized for temperature control, and processed air with a relatively low humidity ratio is supplied into indoor spaces for humidity control. With the support of the 11th Five-year National Science and Technology Support Program of China (2006–2010), a number of organizations, including design institutes, research and development institutions, and equipment manufacturers, were involved in collaborative research and development of THIC systems. Newly developed handling devices and practical applications of THIC systems have been continuously promoted in recent years [4].

Since the appearance and prevalence of SARS, thousands of medical workers are infected to death [5]. Back then, more and more hospital wards adopted the temperature and humidity independent controlled air-conditioning system (THICACS), due to liquid dehumidification sterilizing function. As is known to all, not only can THICACS eliminate the insanitary moist condition of the condenser, it also shows significant advantages of energy conservation (Jang and Liu 2006). To some special functional buildings such as hospitals, creating and providing a sanitary and healthy indoor air environment is very necessary to meet the basic requirements of patients and medical workers. Therefore, THICASS is gradually becoming a mainstream HVAC system and has a bright future of varied application. However, because of its expensive initial investment, the application of THICASS is still limited a lot. What's more, as the patients are in different shoes of their health status, they prefer a more flexible HVAC systems which can be controlled by their wills according to their physical and mental needs. Unfortunately, the conventional THICASS that work as one integral HVAC system can only be modulated to one condition in the whole space. Now that we have achieved this advanced HVAC system, we can make systems better to completely satisfy what the clients really desire. Back to this paper, based on THICACS, we retrofit it into personalized ventilation and radiation systems, which can improve the economical and energy-saving performance and make it better prompted and generalized.

2. Methods

In this paper, a typical hospital ward is chose to apply for the THICACS to be simulated the specific parameters distributions of temperature, humidity and PMV by CFD measures. With the platform of electronic computer and broad application of various mathematical method of discretization, CFD can solve all various practical problems about fluid dynamics, including conduction, convection and radiation of heat, by methods of the numerical experiment, computer simulation and analysis. The basic characteristics of computational fluid dynamics are numerical simulation and computer experiment. In simulations of this paper, the heating and cooling methods of THICACS is set to roof radiation. It's because that, compared to roof radiation, floor radiation that can be accepted by patients will be obstructed by hospital beds. Based on the simulation result, some important parameters, for instance temperature and PMV are analyzed to evaluate the thermal comfortable level. Then, we can make adjustments about the arrangements of THICACS to reduce the cost of material and optimize the performance of HVAC system.

2.1. Steps of simulation and retrofit in THICACS

In this paper, CFD software is used to simulate and improve the THICACS of the ward. All of the simulations are applied the discrete coordinates radiation model to calculate the radiation effects. The conventional ventilation is contrasted with the personalized ventilation by the simulation results. In the second step, the compares are made between the single integral radiant panel and the several discrete radiant panels. In the third step, some adjustments are made in the simulation including the array location and amounts of the discrete radiant panels. With the continuous processes, we found a reliable solution to ascertain and arrange the individualized radiant panel and the personalized ventilation openings to improve the economical and energy-saving performance of the HVAC systems in the ward.

2.2. Boundary conditions model assumptions of simulation

A typical hospital ward was chose in this simulation. With capacity of containing three patients, the ward have 8 persons in total, which means 3 patients, 3 accompanies and 2 medical workers . Besides, there are also 2 lamps and 1 TV in the room. Several assumptions are made as preconditions in the model. The first assumption is that except the only one outer wall, all of rest inner walls and floors are adiabatic. The second one is that the discrete ordinates radiation model are adopted to calculate radiation. The third one is that the heat and moist load of human bodies are all the same.

The specific information of the ward are presented in the following Table 1 and Fig. 1.

Table 1. Information of the chose hospital ward

Geometry	7m*5m*3.9m	Lamp	2*60W
Wall thickness	0.28m	TV	1*120W
Heat transfer coefficient	$1.0W/(m^2 * K)$	Opening	3*0.5m*0.5m
Ambient temperature	36.4°C	Fresh air temperature	23°C
Window area	4.41m ²	Fresh air humidity	9 g/Kg
Person	8*49.25W	Moisture gain	0.016 g/s

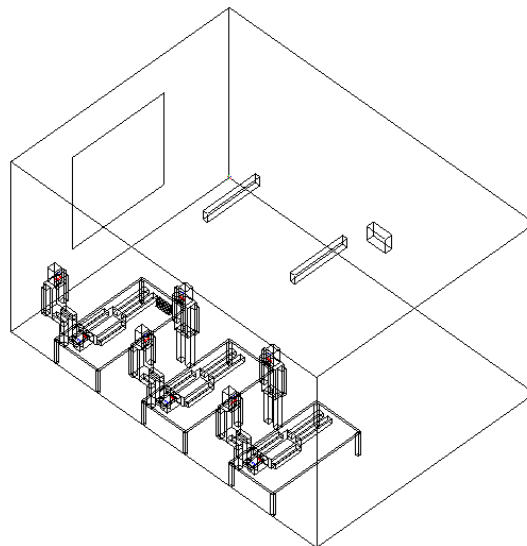


Fig. 1. The basic arrangements of a triple hospital ward.

3. Results

3.1. Physical models of conventional and personalized ventilation

The aim of this contrast is to pick out a better air supply method by comparing with PMV in occupation areas. We designed two temperature and humidity independent control systems separately in two completely same hospital ward. Both of the two wards applied radiation roof for heating and cooling while the fresh air system undertake the duty of handling humidity and part of sensible heat load. The only difference between these two wards is the arrangement of fresh air supply. The conventional ventilation model supplies fresh air from upper wall and exhausts from lower wall, while the personalized ventilation supplies fresh air separately from outlet whose height is 0.7m which is very close to hospital bed. The main task of supply air is to eliminate the latent heat load of 8 human

bodies. The velocity released humidity of each person is 0.016 g/s and sensible heat is 60W. To personalized ventilation, three outlets are distributed in same distance on the wall. The velocity of supply air is 0.1 m/s and temperature is 23°C. To conventional ventilation, the dimension of outlet is 0.25m*0.1m and the velocity of supply air is 3 m/s. Except above parameters, all of other sets are totally between two schemes. The specific arrangements of both hospital wards have been shown as following Fig. 2.

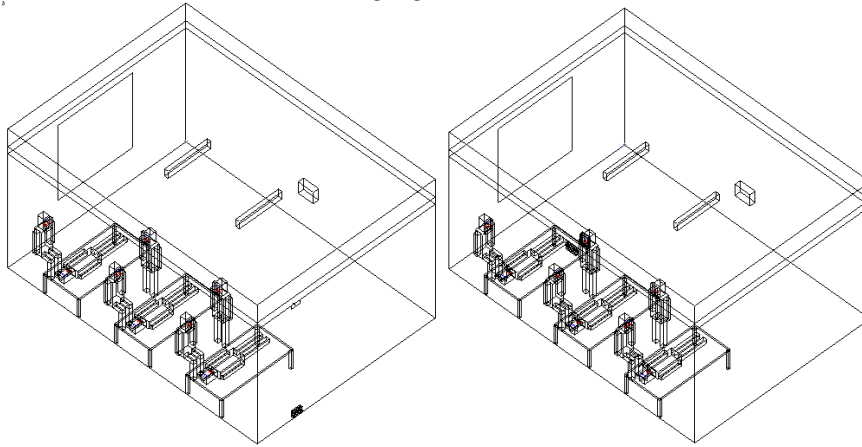


Fig. 2. The arrangements of conventional and personalized ventilation.

3.2. Results and analysis between two ventilation systems

The results of simulations are revealed by distributions of temperature and PMV at height of 0.7m.

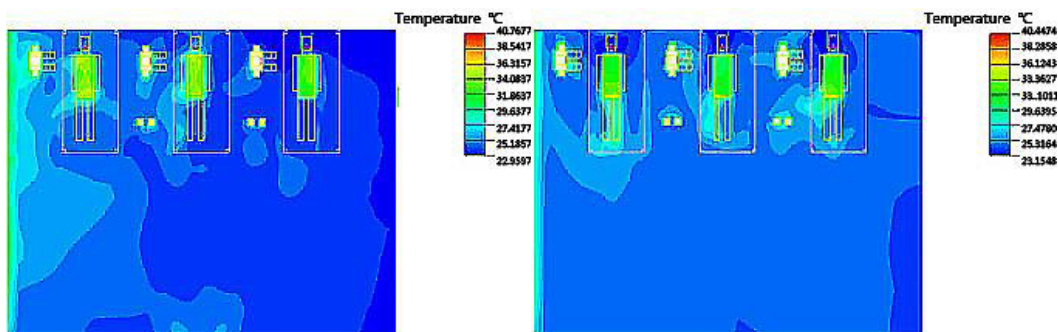


Fig. 3. The temperature distributions of conventional and personalized ventilation.

Compared with temperatures distributions in Fig. 3, the temperature of almost all areas is about 26°C, except little place near to the exterior walls. However, the outlets of personalized air supply system are separated in equal interval, which can lead to some outlets very near to the exterior walls and decline the temperature of that area.

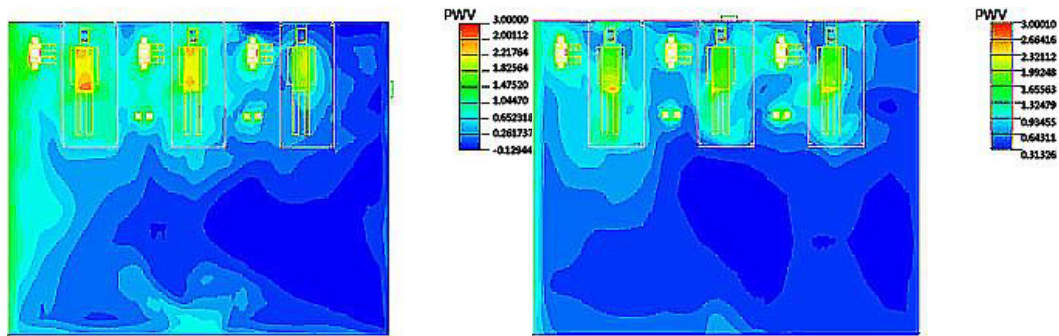


Fig. 4. The PMV distributions of conventional and personalized ventilation.

As we can see in Fig. 4, for two hospital wards, the PMV of most areas are within the range of 0-1, which can be up to the common standard of thermal comfort level. The PMV values on the side of gathering patients are higher than another side, which means the thermal comfort level of this side is worse than the another side. Besides, the areas closer to the exterior wall have higher values than areas far away from them. It's reasonable because the areas of high occupancy density or closer to exterior walls obtain more heat from surroundings which can lead to a higher temperature to increase thermal sensations of people. Compared with Fig4, the PMV of conventional air supply system is within the range of 0.7-1.8 while that of 0.3-0.9 in personalized air supply system. It manifests that personalized air supply system has a better thermal comfort level which can bring patients more meticulous care.

Adopted personalized air supply method, the fresh air can be breathed in by persons as soon as it comes out from outlets, which can also take away the latent heat released by persons. What's more, the fresh air can be divided equally to everyone, which can never be achieved by conventional air supply system. To sum up, the personalized air supply system is better, especially in hospital buildings.

3.3. Physical models of conventional and personalized radiation

As is known to all, when we apply for radiation heating or cooling in a space, the conventional arrangements of ceiling radiation panels are scattered all over places under ceiling. This approach does balance the temperature of every corner of space, however, the consumption of radiation is high and the cost is also expensive. Actually, it's not necessary to lay down radiation panels to cover everywhere of ceiling especially in a space like hospital ward. In a hospital ward, the beds are fixed, so as to positions of patients. All other persons are surrounding around patients including accompanies and medical workers to execute daily duties. Hence, a strong occupation feature of hospital wards is that most of person activities are concentrated in fixed part of the whole place. The objective of controlling thermal comfort levels is to serve human with a comfortable indoor environment. Therefore, there is no need to control thermal comfort level of everywhere, which only cause a massive waste. What we should do is to focus on human occupation areas and control PMV level strictly rather than try to do that in all places. This is what we called personalized radiation and can save a lot economical costs and energy consumptions.

To conventional radiation, each side of hospital ward is equipped with 5 radiation panels in same space whose temperature is 20°C. The dimension of these panels are 2m*0.6m. To personalized radiation, all 8 radiation panels are distributed in same side which is just above the patients. All parameters related to ventilation is totally same. The specific arrangements of conventional and personalized radiation are as following Fig. 5.

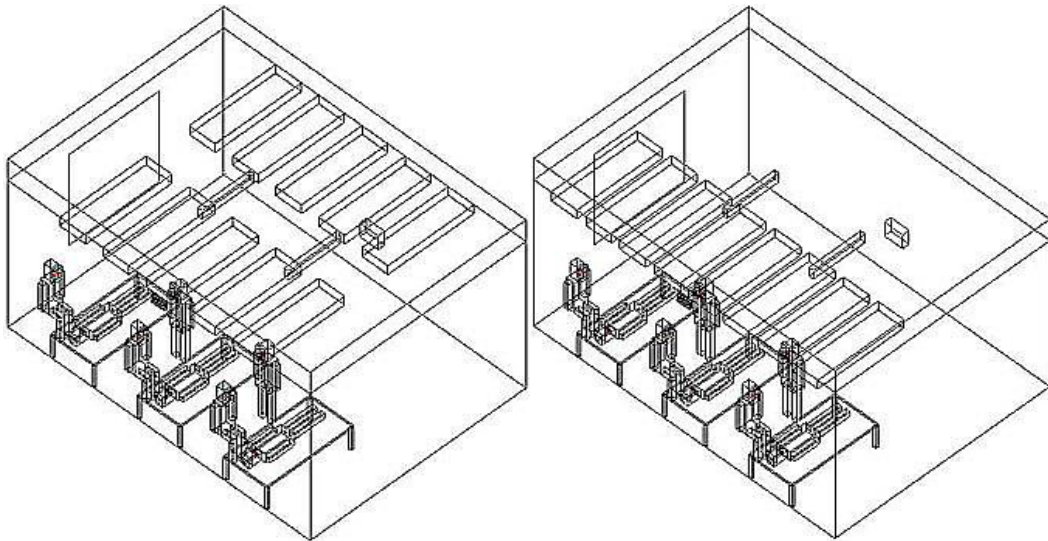


Fig. 5. The arrangements of conventional and personalized radiation.

3.4. Results and analysis between two radiation systems

For conventional radiation, ten radiation panels are scattered uniformly under the roof, each side with five panels. The interval between panels is 0.4m. The length of radiation panel is 2m and the width is 0.6m. The temperature is set to 20°C, which can assume the part of sensible heat with no dew formation. For personalized radiation, all radiation 8 panels are placed on the side of hospital wards to aim at controlling the PMV parameters and creating a comfortable thermal and humid environment in human occupation areas. The interval between panels is 0.2m. The distributions of temperature and PMV are as following.

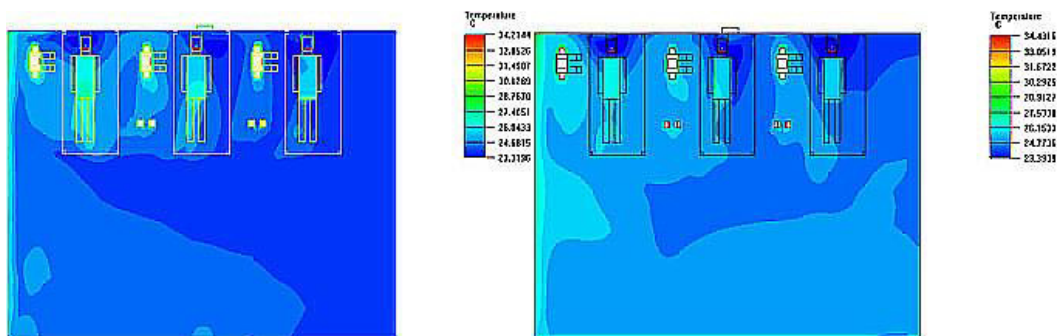


Fig. 6. The temperature distributions of conventional and personalized radiation.

As is shown in Fig. 6, both conventional radiation and personalized radiation have a comfortable thermal and humid environment which is satisfactory. Compared Fig6, we can find that the temperature of both radiation patterns is under 26°C which conforms to the design requirement of indoor thermal and humid environment. Although less 2 radiation panels, the personalized radiation successful controlled the temperature under 26°C, especially on sides with patients. However, there're also some differences between two methods. If we make a comparison only on the opposite side of patients, the personalized radiation has higher temperatures than the conventional radiation. Considered the fact that little people stay in that area for a long time, it's acceptable. Moreover, the temperature in this area is also at the range of 26~27°C, which is also moderate.

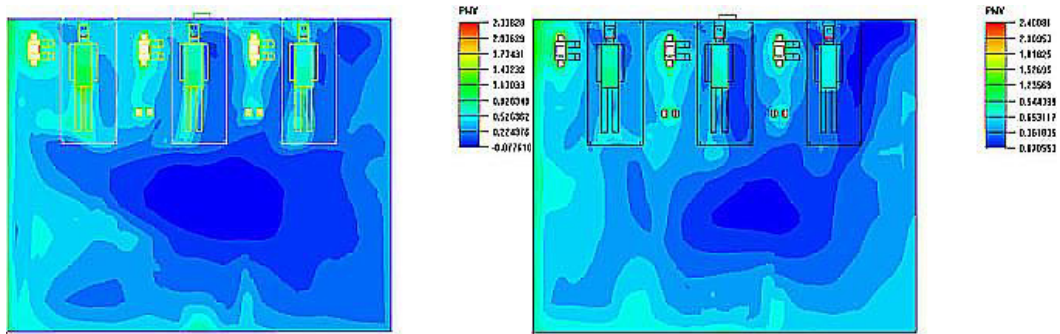


Fig. 7. The PMV distributions of conventional and personalized radiation.

Now we make a comparison of PMV between the two methods by Fig. 7. In conventional radiation, the value of PMV on the side of hospital beds is under 1.1 while the value of rest areas without human occupation is under 0.8. In personalized radiation due to concentrated radiation panels on the beds' side, the PMV on this side is under 0.7 while rest areas are under 0.9. Therefore, compared with these two radiation, the personalized radiation has a better indoor air environment which can be more comfortable to patients.

4. Discussion

We have made detailed load calculations to chosen three-person hospital wards. In this room, sensible heat load is 1624W. Excluding part of cooling capacity of 23°C fresh air, which account for 270W, the remaining sensible load is totally eliminated by radiation panel. Thus, radiation panels need undertake 928W sensible heat. Based on research papers, when the temperature difference between radiation panels and indoor air is 6°C, the heat flux is 64 W/m^2 . The laying area is approximately calculated at 14.5 m^2 . In our above schemes, the most proper scheme only contains 8 radiation panels whose area is 9.6 m^2 . The conclusion can be drawn from simulations in the given triple hospital ward that after adopted the personalized ventilation and radiation in THICACS, we can save 33.8% consumption of radiation panels, which shows a great significance on saving energy and prompting the application of THICACS. Considering it's only an example, more tests and experiments should be designed and measured to validate its rationality.

5. Conclusions

To a special space like hospital ward, the conventional temperature and humidity independent control system (THICACS) is very suitable to be applied for. Based on simulation results, several conclusions can be made as follows:

- For conventional THICACS, we can retrofit it with personalized radiation and personalized ventilation methods, on the premise of ensuring thermal comfort in the occupation areas.
- By implementing the personalized ventilation to fresh air and the individualized radiation to heating and cooling, we can reduce the laying area of the radiant panel and improve indoor comfort levels. In the given triple hospital ward, after adopted the personalized ventilation and radiation in THICACS, we can save 33.8% consumption of radiation panels.
- It shows a great significance in advancing economic and energy-saving performance by the personalized ventilation and radiation in THICACS. Once the initial investment was declined, the personalized temperature and humidity independent control system can be spread in a large scale.

Acknowledgement

This research was supported by National Natural Science Funds (51378318), Innovation Team Project of Liaoning Province Universities (LT2013013).

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